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MECHANICAL SCIENCE METHODS

BY

FRANK HENRY SELDEN
AUTHOR OF THE
MECHANICAL SCIENCE SERIES

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PREFACE

This text on methods of teaching Mechanical Science is a revision and elaboration of "NOTES FOR TEACHERS" first published in 1908. The previous edition gives fairly complete directions for teaching this subject as practiced by those who have had opportunity to study this system under the personal instruction of the author. This revision is necessitated by the large number of persons who are using the texts and wish complete methods of instruction and yet are unable to make a thoro study of this system under the personal directions of some one well experienced in teaching Mechanical Science.

In writing a text on methods for a subject so new and unfamiliar as is the subject of Mechanical Science to most teachers and administrators it has been thought necessary to always keep this condition in mind. Because of this lack of knowledge of subject matter on the part of many who will use this text to gain information in regard to the Mechanical Science work, the author has included many statements and paragraphs that would, under usual conditions, not be found in a text on methods.

The Mechanical Science work has reached its present very important position thru such a determined effort on the part of theorists to prove that it could not succeed that it has been most thoroly winnowed with the result, at this time, that its methods and subject matter are as thoroly established and as dependable as those of other subjects. The Mechanical Science work can be placed in any school in charge of a competent instructor with as full assurance of success as can be the case with any other subject of the curriculum.

Two arguments have been most persistantly used against this system. These arguments are mentioned because they persist even after every scintilla of sense has been taken from them by many actual demonstrations. The first is that the exceptional success of the Mechanical Science work is due entirely to the exceptional personality of the author, and that no one else could follow his methods. The work of Mr. Selden's pupils has unquestionably demonstrated that the methods he employs can be learned and used successfully by others. In fact his pupils get substantially as good results as he.

The second argument against this system was advanced while Mr. Selden was emplyed in one of the great teacher training schools with only a private high school in which to demonstrate the work. "Such methods would not be possible

in the public schools" was the criticism.

There are at this time teachers of Mechanical Science employed in every grade of the public schools from the smallest one room rural schools to the large special departments of city schools and the success of the system is fully sustained in all these various grades and under all these greatly varying conditions.

In these schools the Mechanical Science work has displaced the work of every one of the schools usually considered as the leading schools in fitting teachers for the special lines of shopwork, and in no case can it be found that either patrons, pupils, or administrators wish to return to the other systems of work. If this is not evidence enuf that the Mechanical Science work is practical and that it can be taught by any teacher who will make a reasonable effort to learn the system, then demonstrations must be considered useless.

No doubt much of the criticism of this system results from not realizing that it is a development so far in advance of any other system as to be in a class by itself, and that it must be studied from that standpoint and not by comparing it with some other system that may have some features that appear by superficial observation to be the same or similar.

After all explanations have been given and one's best efforts put forth to understand the place in

school, and methods of teaching this subject; there will, no doubt, be statements that will not be understood and questions as to the propriety or possibility of using such subject matter and methods in the public schools. Should anyone reach that state of mind, they ought not to overlook the fact that the Mechanical Science work is now firmly established in a fairly large number of schools and that wherever it has been permitted a fair trial it has given exceptionally satisfactory results. The wise course to pursue, therefore, in regard to matters of doubt would be to reserve final judgment until securing more complete information. Such information will be furnished freely by the publishers of the Mechanical Science texts or by the author in response to personal letters stating definitely on what detail information is desired.

A matter of interest and also of considerable importance to those who use this text is the fact that no longer are the Mechanical Science texts the work of only one person. Since "NOTES FOR TEACHERS' was published the author has received much valuable assistance from those using these texts and to his many faithful students who have aided in making the work what it now is he here records his sincere appreciation. To his present assistant, Mr. J. W. Wunn, who has given much time in assisting in the preparation of this text very personal acknowledgements are due.

CONTENTS

GENERAL METHODS

General Methods. Before taking up the study of methods as applied to the teaching of specific lessons, we may profitably consider some features that apply to the Mechanical Science work as a whole. No doubt some of these general methods would be better understood after completing a study of the lessons in detail, yet a careful study of these fundamentals which cover the general policy of the work will aid much in understanding the specific methods as applied to each lesson. Perhaps the better way will be to make an honest effort to understand these general suggestions as a preliminary to the specific methods and then after completing them review these.

In What Grades. After some years of teaching shopwork to high school pupils this author was very thoroly grounded in the opinion that the use of bench tools could not be successfully undertaken below the seventh grade, except by "overaged" pupils of lower grades. Circumstances, however, led to experiments with lower grades with demonstrations of the following facts and a most emphatic

change of opinion. Because of these actual tests in lower grades this author is now advocating the teaching of Mechanical Science in the fifth grade.

Fits the Pupil. The first lessons in bench work are determined by the principles to be first taught and this determines the tools and materials quite as much as the nature of mathematics determines that pupils shall learn to count before they can learn to add or subtract, that they shall learn to read and write figures before they can set down and solve problems in addition and subtraction.

We further realize that altho persons of any age may learn to count or write yet the habits of society are such that it is much easier or more expedient to learn these things at an early age. The boy of sixteen wants to do larger problems and always is restive if held to thoroly learning to count and read and write at that age, if by some chance he has neglected these things up to that time. It is much the same with pupils in the school shop when the work is made a definite study and fundamental scientific principles are to be learned.

Fifth Grade Best. By beginning the work in the fifth grade all these small but essential details are out of the way by the time the pupil has reached that period of ambitious restlessness common to the seventh and especially the eighth grade. Pupils of these grades should have the problems of planing and sawing so thoroly mastered as to avoid further

instruction on these subjects. They should be able to do all their planing and sawing quite as well as average mechanics, permitting their efforts to be directed to the study of more advanced problems.

The seventh and eighth grades will then be able to take up problems of considerable difficulty with confidence of success. They will also have acquired considerable speed which will permit making projects of large size if the instructor or pupil has occasion to make use of such projects. Seldom, if ever, can this be accomplished except when the work is begun in the fifth grade. If the teacher permits the making of large projects in the eighth grade by pupils who have recently begun the work the result is in substantially all cases a failure to solve the problems, an inferior piece of workmanship and a very discouraged pupil.

Much to be learned. One reason why objection is made to beginning in the fifth grade is that the amount to be learned is greatly underestimated. Sometimes the Mechanical Science texts are criticised because of taking so much space to teach the simple processes of planing and sawing. Such criticisms have, however, always come from those who have had no experience in teaching shopwork as a science. Those who understand the scientific method in shopwork realize that the amount of matter in the text is not too large, and many have definitely criticised the texts by pointing out how

they may be improved by additional information and directions and especially in the first lessons.

As each lesson is studied in detail it will become evident to the most skeptical that the amount to be learned up to the making of the first mortise and tenon is altogether too large to be learned in two years by pupils in these grades.

Amount of time. Closely related to the question of time of beginning the work is that of amount of time to be devoted to each recitation. Like the question of when to begin, we will understand much better how much time to assign after we have mastered the lessons.

We need a rather clear understanding of two factors, the subject matter and methods, before we can answer this question, and a clear definite knowledge of these two factors would leave little room for doubt or discussion. It is, therefore, probably best to state the reasons for the assignment of time which experience has found desirable in a rather dogmatical manner and trust to the further study of the lessons to make the reasons appear justified.

Much Time Necessary. The amount to be learned leaves no question in regard to the amount of time necessary. The pupil ought to have a workable knowledge of the fundamental principles of working solid materials at the completion of the eighth grade. There is a pretty well defined

amount of subject matter to be gone over to accomplish this end. This cannot be covered successfully in less than thirty minutes a day for fifth and sixth grades and forty-five minutes a day for seventh and eighth grades.

Daily Recitation Necessary. The shop recitation in Mechanical Science is not a matter of taking up a piece of material and continuing a process, but the taking up of a problem and continuing its solution. All teachers know what would happen in arithmetic if pupils were given problems too long to be solved in one recitation held but once a week. However long the shop recitation within the possible limits of school time it is not long enuf for the solution of the problem. There is, therefore, but one possible arrangement of time for the best work and that is to have the recitation recur every day.

The author has been so circumstanced as to be obliged to try various plans and the results have invariably led to the same conclusion, that recitations less often than every day lead to inferior work: because pupils forget what they were studying and attempting to understand at the previous recitation. This leads to working blindly and carelessly and mere attempting to complete the project with little or no effort to study the lesson. This has resulted in some cases in the total abandonment of proper methods of work and in almost nothing of value being accomplished by the pupils.

Fatigue. Another very important matter for consideration is that of fatigue. There can be no question whatever in regard to the length of time pupils of the various grades can work with reasonable earnestness. If the time is more than forty-five minutes for fifth grade pupils, as it must be if work is not given each day, they become fatigued and either drop to a low degree of effort or become disorderly. This soon creates habits that gradually extend over the entire shop period rendering any reasonable study of Mechanical Science impossible and leading to the substitution of questionable inducements to keep up an appearance of interest.

Habits. Of great, if not a paramount importance, is the value of the formation of proper habits in study and in work. It is very doubtful if any teacher can accomplish much in habit formation by weekly recitations. There can be no question but that the daily recitation in Mechanical Science can be made a most powerful factor in establishing very desirable habits in both work and study.

Presenting Lesson. From what has been said it is evident that the lesson must be presented as definite problems, each with a definite solution. This will be much better understood after studying the methods of teaching each lesson. It is sufficient at this time to mention this fact which is one of the fundamental features of the Mechanical Science work.

Demonstration Bench. If the work is to be a series of definite problems instead of "getting something done", then the demonstration bench can have no place in the school shop. That a demonstration bench is certain to make imitators, rather than students, of the pupils is but one of many reasons why it should never be used. That no teacher of Mechanical Science would ever think of giving a class demonstration is so evident as to make the discussion of its use at this time entirely unnecessary.

Teachers of other systems who are studying the Mechanical Science work will find their best answer to the question of discarding the class demonstration in a study of the methods of presenting each lesson. Such a study of the subject matter to be taught must soon make clear the fact that it cannot be presented by a demonstration of any sort.

Proper Attitude. Successful teachers of other subjects realize the necessity of establishing a proper attitude in study and this is no less essential in the study of Mechanical Science. The same principles of teaching apply in teaching this subject as in other subjects. The chief difficulty appears to be that in our haste to make a showing in the physical product we fail to get clearly in mind to what the pupil's attention is to be directed. No one will question but that such an error on the part of the teacher of any other subject would result in failure

and we must realize that such an error in teaching Mechanical Science is quite as certain to defeat the purpose for which the subject is taught.

Lessons Are Problems. The teacher of Mechanical Science must realize that the lessons are problems quite as much as the lessons in arithmetic. If the teacher of arithmetic should encourage pupils to see how much blackboard they could cover or how fancy they could make their figures he would certainly find his pupils learning little arithmetic, and when the teacher of shopwork directs the attention of the pupil to the physical product or considers the usefulness of the project there will likewise be little study of the problems and little learned.

The lessons as planned tend to encourage an attitude of study rather than that of making something, but improper methods or carelessness in teaching may fail to utilize this feature of the problems. In fact, even tho the lessons are primarally problems and not projects, incompetent instruction may emphasize the project to the neglect of the problem.

Emphasize Each Problem. It, therefore, is evident that competent instruction necessitates such a complete knowledge of the details of individual problems as will give facility in calling the pupil's attention to each and an insistance that each be actually studied and learned.

It is not enuf to insist that the pupil plane correctly. That would be like telling the beginner in arithmetic to work the problem correctly. The teacher of shopwork must be able to discover what particular problem in planing the pupil is attempting incorrectly and center the pupil's efforts on that one problem. If this is done, and then the proper instruction given, the pupil is practically certain to solve the problem and cannot avoid developing the attitude of study and interest in what he is learning rather than thinking of the completed article.

Reporting to Parents. As these problems arise from day to day he is quite certain to tell his parents of his difficulties and successes. A very few such reports are pretty certain to interest his parents in the real values in his work and develop in them a correct attitude that will even go beyond that of the pupil, because the more mature the mind the more it will appreciate the larger values. The parent will soon cease to ask the child what has been made and instead ask what has been learned. When we consider that the lessons are sufficiently numerous to permit of one being learned each day we can easily understand one of the reasons why the Mechanical Science work can create so much greater interest than the making of projects that are the same one problem day after day and often week after week until the pupil is thoroly tired of the task before he is able to see that he has accomplished any-

thing that he is sure of with always the possibility of defeat in the end. And when thus defeated it is a total and serious defeat that may cause the pupil to discontinue shopwork or leave school.

Influence of Parents. Sometimes the attitude of the pupil is greatly influenced by parents who have by some means been given erroneous ideas in regard to the shopwork. To change this influence is not always an easy task. Perhaps the better way is to go patiently ahead and trust to the results convincing parents that you are using the better methods. This should require but a brief time for accomplishment, for if you are really teaching the children something worth while their parents will find it out.

Practical Work. The casual observer of the Mechanical Science work sometimes criticises the projects used as not being practical, as not interesting the pupils and as not fitting them for industrial employment. That this is purely the result of superficial observation is absolutely certain for there is an abundance of evidence that no other line of public school shopwork can show by actual records of pupils such large values in this respect. The Mechanical Science work wherever taught is a standing challenge to all other systems to show as large values in fitting pupils for actual industrial life.

Reasonably Expected. That this practical value should be expected is but reasonable when we con-

sider the fundamental character of the instruction, the intense interest it arouses, and the masterly manner in which the projects are completed.

Psychology. After all the demonstrations of this work, after all its successes in school and out, we are sometimes asked if it is in harmony with the theories of modern psychology. There can be at present but one answer to this question and that answer is that modern psychology has no definite theories in regard to the Mechanical Science work.

The author has kept pretty closely in touch with what has been done along these lines since making a special study of the best that was afforded in his senior year over thirty years ago and can state with the utmost confidence based on actual knowledge of facts that modern psychology has utterly failed to make use of such subject matter in its experiments as can be relied upon to yield dependable information in regard to this subject.

An Open Question. So far as modern psychology is concerned it has nothing at present to offer worthy of consideration in regard to the methods of teaching or the values in training the mind of the use of the science of working solid materials as a subject of study in any grade in any kind of school. The question of the place of Mechanical Science in the school curriculum as determined by the application of psychology remains entirely an open question and must continue to so re-

main until those who are making investigations along this line are able to make use of proper subject matter in their experimentations.

Some Data. On the other hand, teachers of Mechanical Science have accumulated a considerable amount of very reliable data indicating that the study of a subject so fully in harmony with the nature and interests of a pupil tends to improve the entire mentality of the pupil, not only in such subjects as are closely related to shopwork but in all subjects. This does not mean simply the forming of general habits of study or mental action, but a strengthening of the entire mentality for any work properly required of it.

Not the "Formal Discipline Theory". This is not the place for a discussion of this question, yet we must not overlook the fact that the general building up of the mental powers resulting from the use of such subject matter as is contained in the Mechanical Science work is an entirely different process from that which is attempted by the use of a subject for the purpose of formal discipline.

That the proper study of Mechanical Science does strengthen the mind for all lines of proper intellectual effort has been demonstrated to a sufficient extent to make a denial of this statement simply to exhibit a lack of information in regard to this subject as a factor in education.

LESSON METHODS

An Introduction. Lesson I. may be called an introduction to the shopwork. It is not to teach about lumber or lumbering, but rather to take the attention of the pupil by connecting up with what he already knows and prepare him to enter upon the line of thinking which is to follow. Because of this, no drill on this lesson should be given. It contains no facts essential to the work except, possibly, the name and illustration of a crosscut saw. This name should be sufficiently enforced to cause the pupil to understand the impropriety of applying the name "crosscut saw" to the hand saw which he will use for crosscutting later in his work.

Studying Woods. The suggestion that information about woods will be gathered a little at a time as different woods are used leads to the next lesson in which some observations are made.

The teacher ought always to keep in mind that in the shop only those facts about wood affecting its use as a material of construction should be considered. In the first lessons only those facts of immediate importance should be considered.

Knowledge Should be Orderly. The shop is not a place for studying anything and everything. Knowledge to be worth the getting must be held in the mind in an orderly manner. This cannot be done unless it is put in in an orderly manner. To discuss the characteristics of wood such as the shape of the pine leaves at this time is a mere memory task and of no value were it to be retained which it likely would not be. The shape of leaves should be learned as a part of the study of the growth of trees and taken up from that standpoint by a proper approach in a properly arranged course in this branch of botany. Gained in this manner, the pupil would not only retain the information in a usable form but would be in a position to add to his knowledge much more with little effort.

It is extremely doubtful if ever the poorly and illogically imparted information which can be given as side talks in the shop consumes less time than a properly arranged course giving all the information that would be given in such talks together with the necessary additional facts essential to the logical study and understanding of the topics.

g38As to the matter of interest, there can be no question but that the logical treatment by a separate course will result in a much greater interest as well as in larger values in all other respects. If we are careful to distinguish between interest and curiosity, we will discover that the shop teaching of unrelated

matter gains curiosity only, that it seldom, if ever, leads to interest in the subject.

Let it, therefore be understood that in all the shopwork only such facts about materials as bear a logical relation to the shopwork in the working of those materials are to be discussed in shop recitations.

A Tool for Use. The pupil wants to make his piece smooth. He is, therefore, interested in such features of the plane as he needs to know to accomplish that result. His interest in the plane is as a tool to use and not as a specimen to study. Because there is no interest in the plane, make no attempt to study it at this time. Do not mistake the curiosity of some pupil for interest. Every part of the plane will at some future time have an interest for the pupil because of some work necessitating a knowledge of that part in order to better accomplish some piece of work—because of its use in solving some problem. When that time arrives is the time to study that part and not before then.

The text gives data in this lesson in regard to the plane so that as it is needed the pupil can return to this place and secure it. The information would be scattered thruout the lessons were it not that different pupils will require the various items of instruction at greatly differing times.

Planes Sharpened by Teacher. Before giving the planes to the pupils they should be sharp and

set for the work so that no time will be taken in attempting to adjust them until there is a basis of knowledge as to the use of the plane on which to study the adjusting. After the pupil has learned the purpose of the plane, how the removing of the shaving affects the surface, he will then be able to judge in regard to the thickness of the shaving to be removed and will have a purpose in learning to adjust the plane. The same is true in regard to sharpening the plane, and no pupil should have anything to do with sharpening a plane until he realizes the benefits to result from having it sharp or sees the disadvantage of having it dull. This may necessitate not only giving him a sharp plane to begin with, but may require having it sharpened for him several times.

Learning Names. Names should be learned by use, not by memory drill. The teacher should speak of the jack plane and smooth plane and see that the pupil also uses the entire name. It would be much better to write the names of all the tools as one word instead of as two words or compound words as is now the case with many of them.

Those pupils who have difficulty in learning the few names needed should not be made to feel their misfortune but carefully trained at first in the use of the most essential names and others added from time to time. The number of such words to be learned in the entire course is not large and all pu-

pils, under careful instruction, will be able to learn them. The names are a convenience, not a necessity, especially in the first lessons.

Follow Directions. At this time take every opportunity that offers to emphasize the necessity of following directions. Unless this is done, much trouble will occur later in the course. It is not necessary to insist that the way the book gives is the only correct way. A reason that is always valid and which ought to satisfy the pupil is that in order to learn the principles which are being taught he must follow the directions given in the book. After going over the work and thoroly mastering it he will understand the reasons for the methods given. This eliminates all arguments from the "practical workman" standpoint. Usually, if not always, it will be found that practical workmen use the same methods as those given in the text. Most practical workmen have not carefully considered all the methods of work which they use and therefore cannot be considered authority.

Substantially Correct. Every tool process and every method of work given in the entire series of Mechanical Science texts has been most carefully studied and its use decided upon only after a thoro enquiry in regard to the practices of practical workmen. Some of the methods of tool usage given in the author's early texts were most severly critized and condemned by a well known author of manual

training or industrial arts texts, but his later works have been changed to harmonize with the practice given in the Mechanical Science texts. He has even gone so far as to take without permission illustrations and text from this series and sell it as his own. The considerable use made of these texts by others who have issued various publications over their names should give them sufficient authority and standing to relieve all teachers of Mechanical Science from any worry in regard to their correctness or authority.

First Link. With this lesson the first link in the unbroken chain of thinking in our shopwork is begun. With a piece of pine in hand the pupil inspects it, first in his own way and then, if necessary, at the direction of the teacher. That the work may begin properly, great care must be taken in having suitable pieces of material. Thruout the entire course there is no lesson which depends to so great an extent upon having just the right kind of stock. The piece must be of even texture and soft, easily worked material. There are a number of kinds of wood that fulfil this requirement, but only one that can usually be obtained. This is the better quality of the heart wood of the matured white pine, pinus strobus. Pine saps or pieces of heart wood in which the annual rings show considerable difference in density should not be used. The grain should be nearly straight.

Getting Out Stock. Pieces for this lesson may be ripped from $1\frac{3}{4}$ inch stock, but better results will be had if they are ripped from $1\frac{3}{8}$ inch stock as this gives machined surfaces on the two sides.

Planing in Wind. If the pieces are machined from good stock they are likely to be nearly true in all three ways (the three tests for first surface), and, therefore, may be smoothed without learning the lesson. Because of this, it is better to take off from two diagonally opposite corners two or three shavings before the pupils see the pieces.

The Problem. The problem of this lesson is to find something to be done. The problem for the teacher is to see that each pupil actually finds the right problem. The pupils are to see that the surface needs to be made smooth and straight. This leads to the next link of the chain—tools and methods of smoothing and straightening.

LESSON IV.

Planing First Surface

Plane Surface Important. There is scarcely an occupation dealing with working solid materials that does not have as the foundation of its work a plane surface. This is true of all woodworking and all metal working trades, stone cutting, masonry, and many others. It is not essential, and perhaps not best, to always state this fact to the pupils; but they should be taught at once the nature of a plane surface so thoroly that they will not only gain merely from learning it, but also have so clear an idea of a true plane that they will be able to make use of their knowledge in any relation required. To the pupil this lesson is learning to plane, to the teacher it is much more.

Attention to Shaving. You will discover that the vital point in this lesson is attention to the shaving. At first every shaving should be examined to determine its size, shape, and where it came from and what change it made in the surface. If you can get the pupil interested in these questions you will make shopwork truly educational, and will have little trouble in later lessons on planing.

Review Lessons. Review all of the lessons that have to do with the truing of this surface so that you

can answer any questions which may arise. You also need to have the whole subject of planing clearly in mind that you may direct the pupil in the most orderly manner of study. In the planing as well as in all other parts of the studies in working materials there is not only a best way in which to do the work, but also a best order in which to learn the work. This may not be the same for each pupil because of the nature of the piece he is working or because of some mistake he may make in his work, yet in every case there is a best lesson or problem for the next step for each pupil. To make the selection and direct the pupil necessitates a very comprehensive knowledge of the work and also of the difficulties which the pupil may encounter at each step. Some pupils may complete this lesson in a few minutes, others will require the entire recitation and a few may require even more time. Those who are ready should be allowed to proceed with the next problem as given in the fifth lesson.

If the teacher is inexperienced with this system of work, he will likely require several recitations in which to analyze the lessons so that each pupil will be able to direct his attention definitely to each separate problem.

Undirected Efforts. It will be found that those who fail to complete the lesson in one recitation have failed because they have not understood each step in the process. They have been simply planing to get

the surface true without a definite idea as to what is to be done to make it true. They have not been able to separate the lesson into its parts and thus bring it within the range or power of their comprehension. The work of the teacher is, therefore, not to show the pupil how but rather to separate the lesson into comprehensible parts and direct the attention of the pupil to the specific lesson. He must then see that this lesson is learned.

First see that the pupil realizes that he is trying to make the piece smooth. The machine marks will have long since disappeared but there will be other rough spots in their place. Have the pupil direct his attention definitely to some rough place and then study how it can be made smooth. When this has been accomplished, call his attention definitely to his having found out how to remove such rough places and let this be to the pupil a lesson learned.

Next direct attention to the next easiest problem in roughness and see that it is solved and that the pupil again realizes that he has learned a lesson and that he is gradually becoming master over rough places. Be very careful not to solve the problems for the pupils. See that they not only solve them, but also that they have a full realization of having solved them and that they experience the pleasure that comes from winning out in their contest with the bit of wood.

Giving Problems. The work of the teacher of Mechanical Science is as much the giving of problems for solution as is the work of the teacher in arithmetic, and he should be just as careful to avoid solving them for the pupil. When solved the pupil ought always to feel the pleasure of having "got the answer."

The directing of pupils to definite problems is the sure remedy for rapid, careless planing. The thot control of the tool can displace the muscular activity only by having something definite to think about. Rather than scold a pupil for carelessness and thotless planing discuss his work with him and find a problem for him to think about. If necessary, go even farther and explain how he is to take up the problem and how he is to proceed to the solution. The teacher who does this will soon have no trouble about carelessness. This soon means the entire elimination of spoiled pieces—a special feature of the Mechanical Science work and one that is incomprehensible by those who teach other systems of school shopwork.

Problems not Projects. Take every opportunity of displacing the pupil's desire to make something or do something with the desire to have a definite problem and get the pleasure that comes from solving it. This soon will lead to the careful following of directions because the pupil will discover that only by following directions can he solve

the problem. You must understand that these directions are rules for solving problems not descriptions of processes to be imitated. This is the distinctive feature of the Mechanical Science work and a careful comparison of these texts with others will make this point clear. When this is understood, the absurdity of a class demonstration in teaching Mechanical Science is obvious. It is also just as obvious that those who are teaching processes and are unable to teach principles need the class demonstration.

Text Books. From what has been said it is obvious that pupils in the Mechanical Science classes need text books quite as much as pupils in any other subject. For any teacher to give in oral discussions or by use of class notes or to write on the board sufficient directions to make the work the definite study which it ought to be is practically impossible. To attempt to teach the work without text books or with books only at the teacher's desk to be used as reference works is to compel the pupils to concentrate their minds on the projects rather than on the problems. In fact without text books in the hands of the pupils most of them will never discover that they are in the shop to learn something, they will consider that they are there to make something and that they should take as little time for learning as possible that they may the sooner complete the project on which they are working.

One Lesson at a Time. Altho your class will be working at various projects and studying various problems, yet as teacher you must ever keep in mind that each pupil must have one definite problem at a time to study and solve and that your chief problem as teacher is to keep fully informed as to what problem each pupil is studying or ought to study and see that each one works at his specific problem. This is not because these problems are the only ones worth solving but because without this definite attention to specific problems there would likely not be any problems solved.

Guard against questions or conversations that lead away from the work in hand. There are a great many things worth learning, but no extraneous information can be of as great value as that which applies to the problem on which the pupil is at work.

Dimensions. A dimension is given for the finished piece, but keep ever foremost the study of planing. In some cases the dimension may be used as a check to the thotless worker, yet to require its use for this purpose would indicate that the teacher had failed to properly direct the pupil's study.

It must be understood that we learn one thing at a time and that working to size is a problem that must follow learning to true a surface. It is bad pedagogy to try to teach the two problems at the same time. After the pupil has learned to true a

surface and stop at a line he is then ready to learn to plane to dimensions, and experience shows that he will be able to solve the problem of planing to dimensions without difficulty.

High Grade Work. It is this step by step mastery of each problem in its order and having the problems arranged according to their scientific sequence that makes possible the high grade of work peculiar to the Mechanical Science classes. This also leads to exceptional speed in the later problems and projects of the course. Yet even of greater interest to the pupil is the pleasure that results from a study in which the pupil knows day by day that he is definitely progressing and gaining in power to solve more difficult problems, to do more difficult tasks.

Master Each Lesson. The teacher must be very particular to see that each lesson is mastered as it presents itself in the project. It is fully as essential that certain lessons be mastered before others are attempted as it is that the propositions in geometry be demonstrated in a certain order. Much, if not all, of the trouble about poor workmanship and spoiled pieces and discouraged pupils and dropping out of class and disorder and poor condition of tools is directly caused by pupils attempting problems for which they have not been properly prepared by a logical arrangement of the work that permits definite instruction on fundamehtals.

Outside Work. In some schools you will need to guard against the dissipation of the pupil's time and efforts by calls to make bird houses, fly traps, seed testing trays and the many other useful articles that may be needed by some teacher or some patron of the school. These calls may be divided into two classes, those which contain no problems for the pupil to solve and which are therefore a complete waste of the pupil's time and those which contain problems for which the pupil is not prepared. Those which contain no problems for the pupil to solve may be done after school hours by voluntary workers. They should never be done during the regular class recitation because it is robbing the pupil of his lesson, it is robbing the tax payers who are supporting a school rather than a manufacturary, it is robbing the teacher who is expected to teach all that can be taught in the time assigned to this subject and which cannot be done if the time is wasted in manufacturing.

Outside projects which contain problems for which the pupil is not prepared cannot be done at any time without serious injury to the pupil. Such projects when undertaken must be completed and this necessitates some makeshifts to get the work done. Makeshifts to complete projects of any sort are sure to form a wrong attitude towards the regular work and when once they are let into the school shop it is practically impossible to get them out.

Experience has shown that such work on outside projects is pretty certain to demoralize the shop studies however careful the teacher may be to explain that the outside work is for a different purpose.

Which Plane. No doubt all pupils can successfully begin with the smooth plane, but some will progress better if they have a heavier weight in their hands. The length of the plane is not so important in the first attempts. After the pupils have become somewhat accustomed to handling tools they will select the proper plane because of other differences, the weight and inertia ceasing to be of consequence. The fact that it is possible to do the work with but one plane should not be used as an argument for having but one plane to use. Very soon there will be lessons to be taught that cannot be taught if but one plane is at hand whichever plane that one may be.

Preparing Planes for Pupils. Before allowing the pupils to use the planes, examine each and be certain that it is in proper condition. For the first lessons in planing the bits are made quite rounding so that they will require less strength. In the use of any tool the first attempts consume much more strength than is necessary. This sometimes leads to improper or awkward habits of use. This may be avoided in our first lessons in planing by so fitting the planes as to require much less strength than can be used after the worker has learned how to apply

his strength. If too much strength is required, the pupil is almost certain to run the plane at an angle instead of straight, as directed. This is sure to cause a great deal of trouble and will likely hinder the pupil ever learning to plane properly.

Planes to Fit the Pupils. From what has been said it is obvious that the planes should fit the pupils. A small pupil requires a plane ground very rounding while a large and strong boy should have a plane that is ground to cut a wide shaving. Neither pupil can do his work to advantage if using a plane that has been fitted for the other, and to compromise by fitting the plane between the two extremes is to have it in poor condition for both. There are also many other reasons for fitting the planes for individual pupils. One pupil may have a piece of wood that is tough and very hard while another is working a piece of the softest pine. These two pupils require planes ground and set very different and it is neither good pedagogy nor good business economy to have both use the same plane.

Individual Planes. There is but one right way out of this difficulty and that is to have two planes for each pupil in the shop. A fairly satisfactory makeshift is to have individual plane irons and have the pupils put their own irons in the plane stocks each time they come to class. This looks very reasonable and satisfactory, but if a little calculating is done it will be found that the tax payers soon pay

out for the time of a teacher who is doing nothing worth while while waiting to have the planes made ready an amount sufficient to get complete individual planes. There are also other losses such as the time of the pupils and the liability that in their haste to insert the irons they will not adjust them properly.

Planes at Rest. When the plane is not in use it must either be laid down on its side or set aside in its upright position. If upright it may be flat upon the bench, resting on a shaving, or resting on a strip for that purpose. Conditions must determine which method is desirable. To lay the plane on its side takes extra space on the bench which is sometimes a matter of importance. There is also the danger of moving the iron sidewise and causing serious damage to work when it is again used. If placed upright on a strip prepared for it there is no danger of dulling the bit and no danger of moving it out of place. In school this method has the disadvantage of either having the stick fastened to the bench at the back side which is too far away from the pupil or if the strip is close at hand for one pupil it will be in the way of another. To have the strip loose is to soon not have it at all.

A considerable investigation among mechanics shows that practical workmen use the strip at the back of their bench and regularly place their planes upon it if the nature of their work is such as to

necessitate reaching so far away in most cases. If their work is small, they are not likely to reach far enuf back to place their planes on a strip. They would then either rest it upon a shaving or turn it on its side when not in use. Of these two methods it is easily understood that the rapid worker who calculates the time of each movement with care would stand his plane upon a shaving as it would require less time in putting aside and also less time in taking up. We believe that the method of resting the plane upon a shaving when not in use should be encouraged by the teacher, but that it should not be rigidly enforced with all pupils. Some pupils will prefer to use another method and so long as their way is not essentially wrong they ought to be permitted to use it. It must never be forgotten that the very fact that we are teaching a science gives considerable liberty in the choice of tool processes so long as they demonstrate the science. This does not give license to use any tool process, but simply to exercise the right of choice when there are two or more which will satisfactorally demonstrate the same principle.

Sharpening Planes. Much planing ought to be done before any plane will require grinding or even whetting. The careful use of the planes which the definite directions encourage makes the matter of sharpening, one of little trouble. There is no legitimate reason why pupils in school should not

handle their tools with as great care as practical mechanics doing high grade work. If the pupils are taught the science of tool usage there will be no abusing of tools. It is probably true that one who is competent to judge could tell whether a school is using the Mechanical Science texts and following these methods by simply inspecting the tools used by the pupils. As you are following the sensible and pedagogical method of teaching one thing at a time and recognize that certain things come first you will need no argument to convince you that if a plane becomes dull before the pupil has gained a pretty thoro idea of how to use it that your duty is to sharpen it for the pupil with as little loss of his time as possible. While sharpening the plane it may be well to let him see how you do it. When the proper time has arrived for the pupil to learn to sharpen his planes see that he actually learns how. He should be able to do this after making a few pieces. Some teachers find that it does not pay to attempt to teach this lesson until the latter part of the sixth grade problems. Some pupils seem to take to the sharpening of their tools very early in the work. They should be permitted, under careful supervision, to sharpen their planes.

Helping or Teaching. The question of showing, helping, and doing work on the pupil's piece arises with the first use of tools. Do not show a pupil how to do his work. After the pupil has studied his text

and made an effort or has asked a definite question showing that he has a need which the text cannot supply, then the teacher may answer his question, direct him to a passage where he can find the answer, question him in such a manner as to lead to the answer, or he may take up the tool and perform so much of an operation or process as will complete the instructions. This should in no case be a showing how to do the work, but such a use of the tools as will lead the pupil to understand that particular part of the work which he has failed to comprehend by his own study and experimentations. It should bear the same relation to the shopwork as the aiding of a pupil to understand a problem in arithmetic. Hence it may be given on the pupil's piece or on another piece in the same manner as a teacher of arithmetic may make use of another problem to lead the pupil to an understanding of the one on which he is working. To tell the pupil how, to simply show how, or to do the work for him is as vicious as working the problems in arithmetic for the pupil while pretending to teach arithmetic.

Questioning. Asking questions that will lead the pupil to an understanding of the problem is undoubtedly the best method of assistance. The shop teacher ought to become an expert in questioning. To accomplish this he must be a master of the subject matter that he is teaching. He must not only know what is said in the texts and where to find it,

but also know the many possible variations from the given methods both good and bad.

In asking the questions as well as in any other help which the teacher may render he must always keep in mind that the end for which he is teaching is not to get the project completed but to have the problem solved—the lesson learned. If because of his help the project has been completed without learning the lesson, then the teacher has been a hindrance rather than a help and the pupil has wasted his time. It is evident that the making of projects in which there are no lessons is a most wasteful procedure.

Independent Work. To have the pupils work quietly and persistantly and properly without the aid or oversight of the teacher is an ideal condition to be striven for at all times. This end, however, is not attained by scolding and trying to force the pupil to do without assistance. Independent working is the result of two factors, first, knowing what is to be done and knowing that it can be accomplished without help; and, second, having a knowledge of the principles underlying the work so that when new problems arise this knowledge will supply the means of solving the new problem and a sufficient number of experiences in working problems with thoro success to establish that confidence that leads to action. To build these two factors into the mentality of the pupil is certainly a very important part

of the work of the teacher. In no other subject of the entire school curriculum is there offered such positive means of accomplishing this end.

To create confidence in power to do work the problems must always be so planned as to avoid any bit of work that the pupil cannot do well. They must also tax the ability of the pupil to the limit. To give the pupil confidence in solving new problems the work must be so planned as to lead not only from the known to the unknown, but also so as to compel the use of the principles rather than a mere memory of what has been done. This must be accomplished by the work itself and not by the directions or suggestions of the teacher.

To understand this feature of the Mechanical Science work is to make clear the reason why pupils who are taught in this system are so much better at doing home tasks than those taught by any other system, altho to the superficial observer the opposite would seem to be the case.

Why Make the Study Piece? No one who understands what must be taught in order to have pupils work successfully outside of school will ever question the necessity of using the "Study Piece" as the first lesson. Those who doubt the advisability of beginning in this manner are not likely to be convinced that it is the best way by any amount of arguments that can be given to them until they have a better understanding of what is to be taught. To

those who have that knowledge no arguments are needed. The only practical answer to the question at this time appears to be that the test of experience is always and most emphatically on the side of using the study piece for the first lessons.

No Argument Needed. Until someone can find at least one school in which this is not done and the results fairly equal to those gained by its use there is little necessity for devoting space to an argument. The writer has visited many schools, has reports from many others and has found in all this extensive enquiry no school or class that does not make use of this or a similar piece for the first lessons doing a grade of work that will at all compare with the work of these schools which do use this piece and system of instruction. This comparison may be made on any feature of the work that is worthwhile. No teacher who is able to use this piece and teach the lessons properly would ever think of discarding it for the making of any "useful" article or a piece differing materially in size or shape.

An Illustration. Since the above was written and published in the first edition there has come to the writer a letter stating that the shopwork in a certain school was to be discontinued. The school referred to is one that has gained a national notariety because of the very "practical" projects which were made in its shops. The work was very carefully "adapted to community needs". It is a fact

that ought not to be overlooked that such "practical" courses tho heralded by "great" educators as "the thing" have never succeeded for any considerable length of time. Why should we continue to chase this will-o'the-wisp of "practical problems" and "useful" articles and "adapting work to community needs" when every experience is against such work and every principle of good pedagogy and educational philosophy condemns it?

LESSON V.

Making Tests

Testing. With this lesson begins the definite testing of the work. The first requisite in doing anything is to know what to do. The tests supply us with our problems or tasks. It is, therefore, of the greatest importance that pupils learn at once to make the tests in exactly the right way. You would not expect a pupil in arithmetic to solve his problem before finding out whether the numbers were to be added or subtracted, yet much of the school shopwork of today is an attempt to true pieces of material when the pupil does not know just where the excess of material is. He often subtracts where he should add.

Test as Directed. It will be noticed that these texts are very explicit in statements regarding tests. The teacher should see that the pupils learn to make the tests exactly as directed. Mere going thru the motions of using the try square is not making a test. Two factors are essential, something to test, and a method of testing. Without both time would be wasted.

Testing the Working. The first effort of the pupil is not to see if the surface is true but to see what effect his working of the surface produces.

First he must, by testing, learn the effect of taking off a shaving. After he has learned the effect of moving the plane in a certain manner he is able to use the plane to produce a certain result. Many pupils become discouraged right at this point because the teacher refuses to accept their work as it is not correct and they plane and plane and test and test but without improving the piece and the teacher continues to criticise the result and encourage or drive the pupils to make the piece true while there is lkely to be no improvement for every time the pupil returns to the task his mind is farther from his problem because the teacher is forcing him to look at the result as a whole and not at the effect of each shaving.

Test Each Shaving. The pupil should test after each shaving until he has a sufficient knowledge of the process to know what effect is produced by each shaving without testing. There must be no question about this. Too much emphasis cannot be placed on the statement that the first requisite in planing is for the pupil to know exactly what the plane is doing at every stroke. Then the pupil is prepared to use it in taking off high places. He should then be able to make his piece as true as a good mechanic would make it, and substantially all properly instructed pupils will reach that standard very early in the course and will make their pieces correct without the criticism of the teacher.

Pupil's Initiative. When the pupil has learned to use his plane so that he knows before the stroke what it will accomplish he has acquired a power that he delights to use and interest is not only awakened but established and the pupil wants to work because he can use and exhibit his power with the plane. All admit that we like to do those things that we can do well, hence the secret of gaining the interest of the pupil in planing is to furnish him a way to learn to do the planing well. This is done by the teaching of such tests as will cause him to master the usage of the plane.

A Difference. A very interesting study for those who wish to find why the Mechanical Science pupils get so much better results than others and become so much more interested is to take the various texts that have been written for shop use or reference and compare the instructions in regard to tests. The first fact that will be noticed is that most of these would be texts have been written from the early issues of the Mechanical Scieuce texts, and second, that the writers have omitted the essential part of the instruction in regard to tests.

Many Lessons. The number of lessons, as numbered in the text, is no indication of the number of lessons the pupil has to learn. This numbering is merely a matter of convenience in grouping the lessons for facility in teaching. The book has fourteen lesson heads for the study piece. If you will

write out an outline of the work, you will find that there are several times fourteen distinct lessons to be studied that are essential to the understanding of the work.

Study Piece Chart. To aid in visualizing the magnitude of what has to be learned by making the piece, a study piece chart may be made. To make the chart, first make an isometric drawing of the study piece. Draw in dotted lines the outline of the rough stock and in full lines the finished piece with gage lines, knife lines, and saw kerfs. Show a part of the piece in each stage of work. Write in order, by groups, around the piece the various lessons to be learned. Write them clock-wise. The chart should be sufficient evidence to convince any one that the necessary instruction cannot be put into less space or require fewer words than are now used in the first fourteen lessons of "Woodwork for the Grades."

This chart ought also to convince any superintendent or principal that any text pretending to give the necessary instruction in less space than that used in the Mechanical Science texts would be a pretense only. To supply the pupils with insufficient directions is certain to fail to teach the science. It is also quite certain to lead the pupils into the mere attempt to make something or get something done in any way to secure the finished, or bluff at finished, product.

Supplementary Tests. The teacher should watch carefully to see that the pupil uses the supplementary tests, such as using the straight edge, only to check up the other tests. All should learn to sight for straightness and, if necessary, the teacher should refuse to permit the use of the supplementary tests after the pupil has had a reasonable time in which to learn to sight for straightness as in Fig. 29.

Written Tests. After the pupils have completed the work on the first surface they should be given a written test, and this test should be repeated until every pupil answers the questions, how many tests, how made, exactly correct.

These first lessons are like learning to write numbers in arithmetic, every pupil must know the value of each digit, and later they must know the multiplication table. The shopwork has the advantage over any other subject in that the few things that must be learned have the appearance to the pupil of being very essential and are in daily use thruout the entire course.

Only the Fundamentals. It must be kept clearly in mind that the texts so far issued and these methods of teaching Mechanical Science apply only to the first fundamentals of the science. They may be compared with a text and methods in arithmetic covering the first four fundamental operations, addition, subtraction, multiplication, and division. The greatest difficulty there is in giving this science

its proper place in our schools and using correct methods of teaching is that of gaining an adequate comprehension of the immense magnitude and importance of this science. It has developed so unobtrusively and so entirely apart from the world in which our educators move that it is all but impossible for them to realize that it is second to no other science either in importance or in the extent of its use and the amount of study and degree of intelligence necessary for its mastery.

Excessive Accuracy. Remember that the tools are not perfect, that even the most carefully fitted surfaces in metal working are not exact, therefore do not strive for the impossible in the wood shop In the test from edge to edge the try square blade should touch the surface at the extreme edges. In the end to end test the straight edge should touch the extreme ends. Between these points there may be slight depressions. How much unevenness may be allowed is largely a matter of judgment, but a rule that will be useful is that no unevenness should exceed in one half the thickness of the shaving being taken off in truing the surface. Altho this rule may be used in nearly all truing of surfaces and edges, it will be found that many pupils will desire to work much closer and such pupils may usually be permitted to do so. A mark of successful teaching is to be able to pass a pupil's work as correct and yet have the pupil insist on making it better. If the

pupil strives only to do the work well enuf to have it passed the teaching has not been effective. If the work is properly taught there will be comparitively few times that the teacher will need to require the pupil to make the piece or surface better after it is presented for inspection. The pupil ought to understand the methods of testing so well and know with such certainty the standard required that no piece would be presented to the teacher until finished, unless for the purpose of asking for some special instruction.

All Tests at Once. There appears to be no other way to learn the tests than one at a time. At first this causes some extra work, but this cannot be avoided. After they have been learned in the order given in the text, then the pupil should be encouraged to use his judgment in applying them in a different order or in using two or all after each working of the surface.

LESSON VI

Looking for Wind

Considered Difficult. With this lesson you take up what to many is an insurmountable difficulty. Looking for wind has been considered by many teachers as beyond the ability of grade pupils. That even fifth grade pupils can be taught to see wind and true the surface out of wind is being demonstrated in every school in which the Mechanical Science system of shopwork is taught in the fifth grade.

Preparing Pieces. The first essential in teaching a pupil to see wind is to have a piece with sufficient wind in it to be easily seen. To make sure of this, it is advisable to plane in wind all pieces to be used for this lesson. About two strokes with a coarse set jack plane taking short shavings off the two diagonally opposite corners will accomplish this end. These shavings should be short so as not to remove many of the machine marks or interfere with the lesson on systematic planing.

What Is Wind? Be sure the pupils understand what the term wind means. Sometimes it is necessary to illustrate the term by use of another piece or by use of a piece of thin board or piece of card board. There is likely to be some benchhook pieces or stock for breadboards at hand sufficiently

in wind to be seen by any of the pupils. It is a good plan to keep a piece of stock for this purpose.

Insist on One Method. Do not permit any variation from the method in the text until the pupil has become thoroly accustomed to recognizing the wind in this manner. After the pupil has learned this method there will be no tendency to use any other. The insistance on looking for a high back corner is the result of experience and should be invariably insisted upon.

Not Practice. Seeing wind is not a matter of practice but of study and understanding. Therefore, all efforts should be made to get the pupil to study until he succeeds in seeing the wind. Do not permit this lesson to be neglected on the first piece. Now is the time to learn to see wind and insist that every one gets the lesson. Should this be neglected it will be found that later lessons are not so well planned to teach looking for wind and that it will be more difficult to teach rather than easier.

Test With Squares. Sometimes it is necessary to have a more exact test. Such a test is given in Fig. 51 "Elementary Cabinetwork". Very seldom should this test be necessary. The teacher ought to be able to see wind readily by sighting as in Fig. 36, and the pupil should soon learn this method.

LESSON VII

Face Marks

Insist on Marks. No special instructions are required for the teaching of this lesson. Simply insist on the face marks being made and used as directed. Do not permit the use of x's or any marks other than these given in the text. Also watch that these marks are not repeated on either the second edge or back side. The marks as given are in keeping with the best practice of mechanics and there is no reason why they should not be used in the school shop. To use any other method of marking is certain to lead to confusion should the pupil continue long in the use of mechanics tools.

LESSON VIII

Keeping Planes Sharp

Insist on Best Method. Keeping tools from unnecessary dulling is quite as important as sharpening them. Insist that pupils study this lesson until they understand it so that they will use the method best suited to their work. The teacher should watch this matter carefully and see that the best method for the piece being planed is used. Do not allow pupils to draw their planes back with the cutting edge rubbing on the wood, and be quite as persistant in not allowing them to form the habit of always using the same method.

Recognize the Most Important. Altho keeping the planes sharp is important, yet it is not good practice to worry a pupil about this at the very first. There is such a thing as spoiling the opportunity to learn the major lesson by an unnecessary emphasis on the minor details. This not only applies to keeping the planes sharp but to many other lessons. In all the teaching it is very essential that the pupil concentrate on one thing to be learned at a time and that there is sufficient emphasis placed on the one thing to have it learned.

LESSON IX

First Edge

Study the Shaving. As in planing the first surface the first problem in this lesson is to determine how and to what extent a certain movement of the plane effects the edge. If you will watch the pupils you will soon notice that some know what their planes are accomplishing and some do not. The task for the teacher is to see that all know. When this is accomplished there will be little trouble about making the edge square and straight.

Care in Testing. In attempting to have the pupils learn exactly how each movement of the plane effects the edge it will be discovered that some pupils fail because they do not make their tests with sufficient care. In fact, it will be found that the chief cause of failure in truing edges is in not making accurate tests. To overcome this, see that the try square is held as in Fig. 42 with the arm and wrist nearly at right angles to the head of the try square and the fingers and thumb so placed that the pressure they exert against the face surface is at the center of the surface. This pressing against the center of the resisting surface should be taught as a principle applicable to all uses of the try square both in testing and in drawiug lines.

Learn to Sight the Edge. See that each pupil makes a faithful effort to learn to test the edge by sighting. Ifyou do not teach the sighting of the edge now, you will have much trouble later in the course. By this time many of your pupilsshould be able to get along with very little assistance. This will allow of spending more time with those who are in need of the help.

Oral Review. You should now have opportunity from time to time to go to each pupil and by orally questinoing on the previous problems find out exactly what they have learned and what they have neglected. You should then be able to point out in the work they are doing the effect of their having neglected to learn some lesson.

LESSON X

Drawing Gage Lines

Study Essential. Because the gage is such a simple tool there is great probability of neglecting to study the lesson. Any one can set the gage and draw some sort of a line without any instruction, but to set it accurately and draw a line that will be correct is a very different matter.

Success in using the gage is a matter of correct method rather than of practice, therefore, there should be much study of the lesson with few lines drawn. Encourage each pupil personally as they begin the study of the lesson to be sure that they understand it before attempting to use the gage and then draw the first line correctly.

If they do not succeed, insist that they find out their mistake before attempting another line and continue studying the problem after each line until they have solved it and can draw every line correctly. Do not permit practice.

Oral Explanation. If there is any doubt about the pupil finding out what has caused the failure, insist that before each attempt he state definitely to his teacher why the previous line was not correct and what change is to be made to overcome the incorrectness. This may seem to take too much of

the teacher's time, yet it is not only the best method for the pupil but also the easiest way for the teacher. When once the gaging is mastered it will require no more attention from the teacher, while if it is not mastered at this time it will likely continue to be a source of great annoyance for a long time and possibly thruout the entire course. Not only will lines be poorly drawn but pieces will be spoiled and projects ruined with no end of trouble for teacher and pupil because of not drawing lines correctly.

Helping is Not Teaching. Perhaps in no other place in the course is it so necessary to insist that the work of the teacher is to see that the lessons are studied and learned rather than to aid the pupil just enuf to get the work done. To have the line drawn by the teacher or with the aid of the teacher, or to pass on without learning the lesson is as unpedagogical as for the teacher of arithmetic to work the problem for the pupil or pass as correct a solution or answer that is incorrect. The pupil is in the shop not for the purpose of drawing lines but for the purpose of learning to draw lines. The lines drawn are the byproduct of the process of learning.

Extra Lines. If the four lines have been drawn and all incorrect a line may be drawn at each $\frac{1}{8}$ inch. This will give more opportunity to study the process, but must not be done merely as practice. In fact, if the four lines have been drawn without a sufficient amount of study to get at least the last one correct

the pupil should be very carefuly eattended to and his lack of properly studying tht lesson brot emphatically to his attention. By lhe time all four lines have been drawn, the teacher should have time to give considerable attention to those pupils who especially need it. If the last line is well drawn the others may be overlooked as the last one is the only one to be worked to. Having one line correct ought to insure drawing lines correctly hereafter. If more than four lines have been drawn they all should be planed off and four more drawn before planing to width.

LESSON XI

Planing to Width

69 This is the first lesson in which the pupil planes to a line. The lesson should not be confused with planing to size which is a problem for a future lesson. It must not be confused with the problem for a future lesson. It must not be confused with the problems of planing square or straight. No matter how square or straight the piece may be, unless the pupil has definitely worked to his line insist on having another line and on working to it. Working to a line is an absolute essential of good workmanship and must be mastered before pieces can be worked to size and this lesson is especially designed to teach this one thing. Therefore, see that this lesson is learned and it will save much time and material later in the course. To afford an opportunity for the teacher to check up the work it is best to have the pupil present the piece for criticism just before the line is planed entirely away. One or two more shavings carefully removed will reduce the piece to a sharp and square corner.

70 **Planing Parallel.** The second part of this lesson is to make one true surface parallel with another. If the line has been correctly drawn and the planing stopped at the line the surfaces will be parallel. To

determine whether they are or not measure with the rule at each corner. Be very particular about how the pupil uses the rule. Unless it is held so that the graduations contact with the surface being measured the measuring will likely not be exact. As it is just as easy to hold the rule so as to comply with this principle the teacher should see that it is done in this manner. It is probably best to inisst on this method of holding the rule even in rough measuring, otherwise the habit of holding it correctly will not be formed.

71 **Personal Equesion.** Why should not the gage be set so that the piece will be full size when the line is planed entirely away? Because we are not concerned about the size of this piece but rather about how to make a piece of exact size. To do this we must get this factor of variation and this is the best way to get it. The amount will vary with different pupils because of a difference in the left of lines they will draw and also because some will plane off a little more than others. Before any pupil can tell how much extra to set the gage he must determine this for himself, and he can do this only by first setting the gage to exact size and then noticing how much too small the piece is after completing the planing.

LESSON XII

Planing to Thickness

Stop at Line. The important paint in this lesson as in the previous one is to have the pupil stop at the line. Be satisfied with nothing less and insist upno seeing the piece just before the line disappears if there is any tendency to work without a line. Some personal explanation may be necessary to make clear that the test differs from that used on the first side. The first test was from edge to edge, there being no lines, this test is from line to line altho the try square is held in the same manner as in the first test. This being the second attempt at planing to size, do not pass any piece with a variation great enuf to be seen by the pupil.

Standard of Accuracy. Some teachers have had standards of accuracy for different grades such as "in the fifth grade all work should be within a sixteenth of a inch of size, and in the seventh grade within a thirty-second of size." All such standards are entirely out of place in Mechanical Science work. If the pupil uses his rule correctly he will be able to measure to a very small fraction of an inch, and if he uses his plane intelligently he will be able to readily work to the correct size as nearly as he can measure it. This should be the standard and noth-

ing else should be accepted. Even then the real standard for different pupils will vary considerably. If the measurement falls exactly on a line of the scale many will be able to work to the hundredth of an inch in planing to width or thickness while others will not be able to see less than a sixty-fourth of an inch. In no case set a standard, have the pupil do his best, make the size as nearly correct as he can.

LESSON XIII

Laying Off Spaces

A Study In Drawing Lines. This is called a scale, for want of a better name, but is in no sense an attempt to make a scale as an instrument for measuring. This system of lines is used because experience has proven it to be by far the best form to use in teaching how to lay off spaces and draw lines.

It is not even intended to teach the nature or construction of a scale, all information being incidental, but to teach how to draw lines for use in making joints, truing ends, etc. If the lesson is taught as given it will have this result.

Watch Details. In drawing lines and in laying off spaces failure results from neglecting the details in methods of using the tools. Study the lesson carefully and be sure that the pupils follow directions exactly. These methods have been most thoroly tested and there is every reason to believe that they will eventually be used by all well informed teachers.

Adopted by Others. When this method of drawing lines was first published it was severely criticised by many and especially by one who has since written several books. In his first book he advocated and illustrated a very different method

but since then has not only adopted this method but has taken this author's illustrations, without permission, to illustrate how to draw lines.

Special Knife. The knife used for this work must be short enuf in both blade and handle to be held as directed. this cannot be done with the usual school bench knives. The one used was designed by this author especially for school use and it should be used even if other styles have to be discarded and new knives purchased. The knife has been adopted and recommended by others than Mechanical Science teachers and can be had of dealers without having them made to order as was at first necessary.

Repeat Scale. It will usually be necessary to make more than one scale, not as a matter of practice but because there are so many things to learn in drawing the lines that a pupil cannot usually get them all before drawing a considerable number of lines. Do not pass as correct a scale that is not well up to standard. If necessary, after two have been made the poorer one may be planed off and another one made, and the work continued in this manner until the lesson is learned.

LESSON XIV

Sawing

Previous Experience. Many pupils come to this lesson with considerable experience in using a saw. Such an experience has often caused the belief that all they need is an opportunity for more practice. This leads to an utter neglect of the lesson and a rapid movement of the saw with little or no thot behind the movement.

One at a Time. By the time pupils take up this study they will vary to such an extent in their progress as to afford the teacher opportunity to deal with one at a time. The teacher ought to know exactly when to question the pupil in regard to the instruction given in the book. With some pupils the proper time will be before any attempt has been made to use the saw and with others the better time will be after the first kerf has been made.

If necessary, stand right by the pupil and see that the directions are followed in regard to moving the saw without allowing it to cut and also that at first it cuts only on the forward stroke. Starting on the forward stroke must be insisted upon.

Saw to Line. At this time pupils should saw close to the line, but not so close as to cut the line away. Later they will saw just far enuf away to

permit of truing the end with plane or chisel. See that they realize that it is easier to saw close to the line than to saw at a distance from it and you will have little trouble about sawing later in the course.

See Right Angle. The cause of not sawing at right angles to the surface of the piece is that the pupil looks down upon the saw instead of looking from one side at the angle made by the saw with the surface of the piece. If you succeed in getting the pupil to look for the right angle at the side of the saw he will have no difficulty in sawing well the first time he attempts to use a hand saw. This is not readily understaood by the pupil but a point that must be taught or there will be no end of trouble in sawing.

Sawing Acrost. Another direction that the teacher will need to emphasize is that of keeping the handle of the saw much higher than the other end until the kerf is nearly low enuf at the back side. Whether this has been done or not can usually be determined by an examination of the kerf, a wide kerf indicating that the handle was lowered too rapidly.

Later, as the pupils will have occasion to use the hand saw some will need to be cautioned to keep the saw at a considerable angle to the surface thruout the kerf. There is some tendency to use a hand saw in the same manner as a back saw, but this is very soon overcome. By actual tests it has been shown

that pupils who have learned to use the back saw will use the hand saw without any directions whatever, often making the first kerf quite as staright and square with the surface as would be expected of a good mechanic.

Recognize Success. If a pupil does satisfactory sawing, before completing the piece, allow him to proceed to the next lesson. If all the kerfs have been made at each $\frac{1}{2}$-inch and the work yet indicates that the lesson has not been learned, have lines drawn for sawing at $\frac{1}{4}$-inch spaces and continue the sawing until the lesson is mastered. There should be no excuse for any pupil not being able to saw fairly well before using all the $\frac{1}{4}$-inch lines.

Remember that sawing as well as planing and other processes used in the study of Mechanical Science depend upon knowledge and understanding rather than practice. Give the pupils the motto "We learn to do by thinking" to replace the one of the bygone craftsmanship age of "We learn to do by doing".

Learn by Study. It is not an uncommon occurrence for a pupil to study the text so well as to saw practically perfect on the second or third line, and sometimes on the first altho never having had a saw in hand before. The essential of good teaching in Mechanical Science is to know that it is study instead of practice that is needed and then make all efforts and devices enforce the matter of study rath-

er than that of practice. That skill which comes from practice only is of very limited value except when acquired in ones permanent occupation.

Many pupils come to the study of Mechanical Science with such wrong ideals and with so many thoroly fixed bad habits of work that it is difficult to properly direct their efforts. They cannot see why they should make any use of a book. They have by long experience been forced to believe that there is nothing in books for any purpose other than to be got to tell or make a bluff at telling to a teacher and therefore when in the shop why should they bother with a book.

The way to overcome this rather reasonable belief as seen from the pupil's standpoint is to compell him to go to the text for the information he needs and see that he gets it all from the text and that he actually makes use of it in successfully doing his work. He will very soon learn that there are some books for his personal benefit and that they are his friends to be consulted in every need in the line for which they were intended.

If necessary, take the piece away from the worker and do not return it until a complete understanding of the lesson has been gained and proven by explaining it to the teacher. In some cases it is best to have a complete synopsis written out by the pupil.

The Mechanical Science Series

This series of texts presents the work of the school shop as a definite science rather than as tool processes or methods of making things. The entire course is arranged in definite divisions with each division arranged according to a definite and logical sequence based on the demonstration of the fundamental principles of working solid materials. Altho this restricts the course to very definite portions of subject matter, yet this subject matter may be studied and the necessary demonstrations made by use of a great variety of materials and projects. This variety is largely provided for by many suggestions in the texts as to modifications of designs, using of different woods and various methods of finishing.

The important and especially interesting fact in regard to the **Mechanical Science Series** is that its proper use invariably yields results far beyond that of any other line of school shopwork. It not only results in a greater interest and far better executed projects, but also yields a value in preparing for industrial occupations that has not been approached by any other line of school shopwork. For complete information in regard to these texts, address,

The Maudslay Press
VALLEY CITY, NORTH DAKOTA

Woodwork for the Grades

This is the text to be used in beginning shop-work in Mechanical Science in whatever grade the work is begun in both grades and high school.

This text contains a large variety of material so arranged as to afford opportunity for selecting exactly the right project for each pupil. There is no question but that in actual practice the use of this text leads to a more perfect adapting of work to individual pupil's needs than is possible with any other text or system of instruction It is a thoroly practical text and pupils who complete the work as given show exceptional interest and ability in doing work at home. No other text will compare with this one in giving power to do work with tools outside of school as records of pupils show, proving this to be a text of exceptional value in developing initiative and industrial efficiency.

The Mechanical Drawings are arranged and graded with great care so that the average boy will, in using the book, learn, without any special effort, to read drawings. The text contains many complete working drawings of projects from simple one-piece projects to chairs and tables.

Wood Finishing

This text is a supplement to "Woodwork for the Grades" and should be used as a text by each pupil. It takes up in the order in which they occur in the course the various problems in finishing.

It first tells how to finish such woods as pine and basswood, and then the more difficult woods such as spruce and fir, and lastly, such fine cabinet woods as oak and mahogany.

It gives various methods of finishing such as shellac polishing, staining, oiling, and varnishing. Grinding finish with pumicestone and rottenstone is treated in a manner that the beginner can understand.

It is a beginner's book and, therefore, tells exactly how to proceed with the first processes. These directions are not merely information in regard to processes but explanations as to how and why and are so complete that a pupil should be able, after doing the work as given in this text, to do a great variety of finishing on all classes of furniture.

"How to teach Wood Finishing" is a similar text with some suggestions as to methods of teaching. On completion of the special text on "Mechanical Science Methods" this text will be discontinued.

Elementary Drawing

This is a text based upon the problems in the shop course in Mechanical Science. Because of using objects with which the pupils are familiar their entire efforts are applied to the study of drawing. Because of this, much more work is covered in a given time and the work is much better understood than has heretofore been usual.

Part One

Part One, now ready, covers the selecting of equipment, line conventions, laying out sheet, use of tools and the making of the most simple drawings.

Part Two

Part Two will probably be ready in October and will cover in a very complete manner the theory of orthographic projections and isometric. It will contain a complete set of sample drawings, mostly actual reproductions of pupil's work supplying the teacher as well as pupils with reasonable standards for study. Several of these drawings are for shop use in constructing very desirable modifications of the projects given in the text on cabinetwork.

Other parts covering the remainder of the usual high school work in mechanical drawing will follow.

Elementary Cabinetwork

This text, the fourth of The Mechanical Science Series, covers the first studies in cabinetwork. A large number of problems are given in a very complete manner. Many of the objects are shown in picture and in orthographic projection with details.

There are many suggestions as to modifications and original designs with such complete information in the text on all details of construction as is needed to lead the pupil to individual effort.

The text thruout emphasizes the doing of every part of the work accurately the first time, thus leading to exceptional speed and that deep interest that comes from a realization of success and mastery.

Home Mechanic's Book

This text is especially useful for the home mechanic as it gives in complete detail just the information that is likely to be needed, and has a complete index that makes easy the finding of any information desired.

This information in regard to laying out work, clamping parts together, finishing, making tops, making drawers, paneling etc., is in addition to the directions for making the various projects and the complete working drawings and pictorial illustrations.